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WO 2003/016669 A2 WO 1998/059151 A1  
US 6431282 A US 3746092 A

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(54) Abstract Title: **Expandable tubular with lip seal**

(57) A seal arrangement comprises an expandable inner tubular 10; and an outer tubular 12. At least one of the tubulars has a lip seal 16. The lip seal forms a ring around the tubular, with the lip itself extending in an axial direction. The lip seal may form a metal-to-metal seal. The seal may be provided in a recess 14 in the inner tubular.

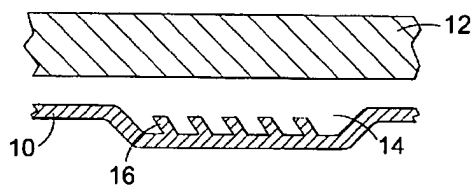


Fig.1

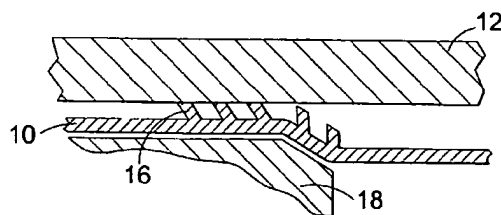


Fig.2

**GB 2404677 A continuation**

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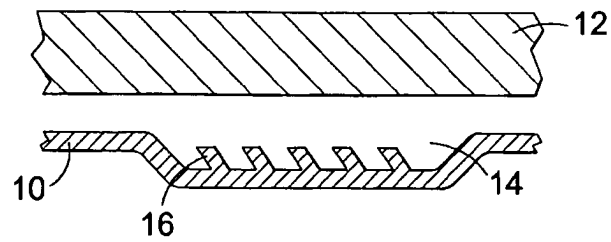


Fig.1

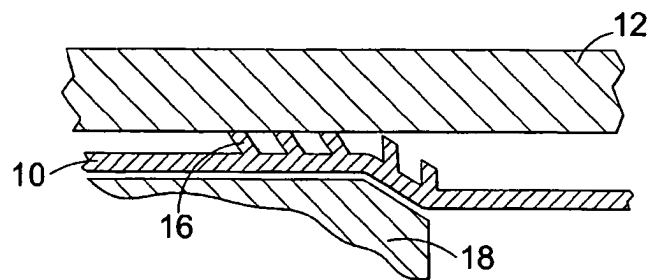


Fig.2

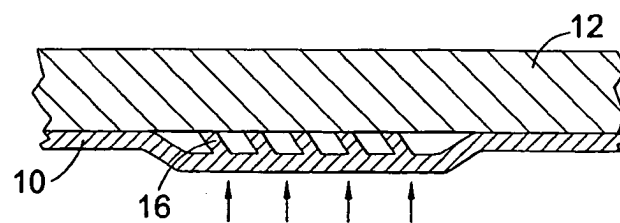


Fig.3

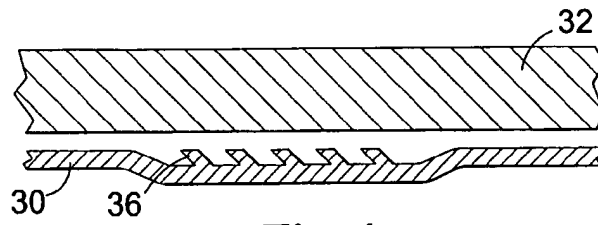


Fig.4

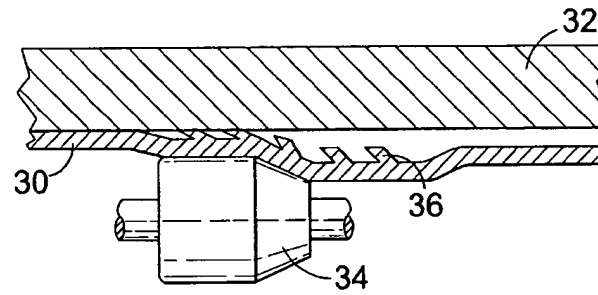


Fig.5

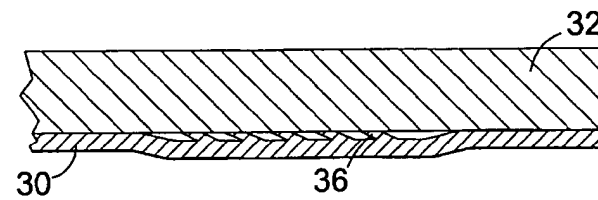


Fig.6

Fig.9

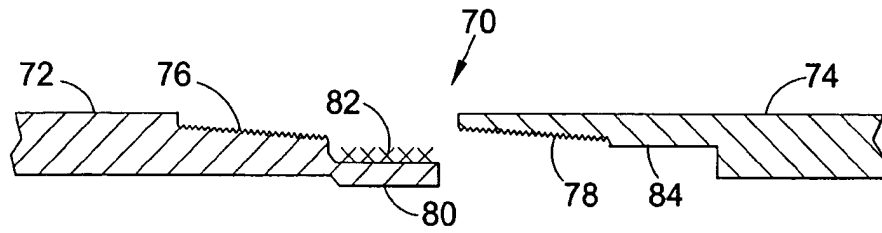


Fig.10

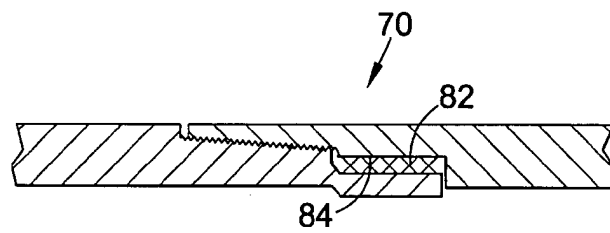


Fig.11

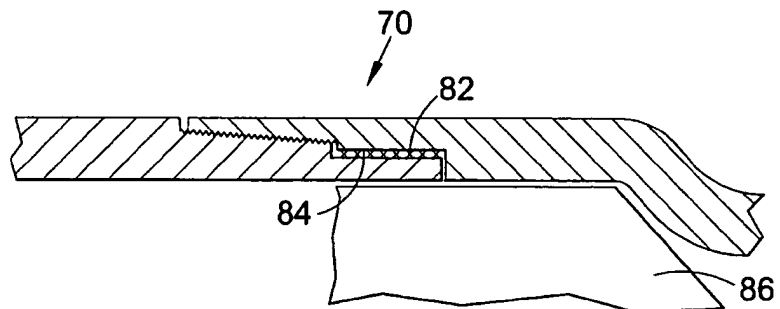


Fig.12

## SEAL ARRANGEMENT

## FIELD OF THE INVENTION

5           This invention relates to a seal arrangement, and in particular to a seal arrangement for provision on an expandable tubular. The invention has particular utility in downhole applications.

## 10       BACKGROUND OF THE INVENTION

          There have been numerous proposals, by the applicant and others, for arrangements for providing a seal between tubulars, where the diameter of an inner tubular is increased to bring the outer surface of the tubular into contact with  
15       the inner surface of a surrounding outer tubular. The seal may take the form of a metal-to-metal seal, or may utilise elastomer seal rings or bands of relatively soft metal.

          It is among the objectives of embodiments of the present invention to provide a seal of this type, which is effective  
20       at high pressures and high temperatures.

## SUMMARY OF THE INVENTION

          According to the present invention there is provided a seal arrangement comprising:

25           an expandable inner tubular; and

an outer tubular,

at least one of the tubulars comprising an axially  
extending lip seal.

According to another aspect of the present invention  
5 there is provided a method of forming a seal between an  
expandable inner tubular and an outer tubular, the method  
comprising:

providing an axially extending lip seal on one of the  
tubulars; and

10 expanding the inner tubular such that the lip seal  
contacts the other of the tubulars.

The expansion of the inner tubular serves to energise the  
lip seal, at least a free end portion of which will be urged  
into contact with the other of the tubulars. Thus, a fluid  
15 pressure differential acting across the seal in an axial  
direction opposite to the orientation of the lip seal will  
tend to further energise the seal. The seal may be provided  
between a wide range of tubular members, particularly members  
to be located downhole, including casing and liner, packers or  
20 metal clad. In these cases the lip seal may provide a metal-  
to-metal seal between the tubulars.

Preferably, the lip seal is integral with one of the  
tubulars, most preferably the inner tubular. Thus, the lip  
seal will typically be formed of the same or similar material  
25 as the tubular, typically a metal, although the lip seal may



be treated to provide different material properties than other parts of the tubular. Alternatively, the seal may be in the form of a separate member.

Preferably, a plurality of lip seals are provided on said one of the tubulars. The lip seals may extend in a common axial direction, or seals may be provided which extend in opposite axial directions.

Preferably, the inner tubular describes an outer diameter and the lip seal is mounted on the inner tubular and initially describes the same or a smaller diameter, thus providing clearance between the tubulars to permit free running of the inner tubular into the outer tubular and a degree of protection for the seal. The lip seal may be provided in a channel or recess in the inner tubular formed by removing material from the outer surface of the tubular, and preferably the wall thickness of the tubular is substantially maintained at the seal location and the lip seal is accommodated within the diameter of the tubular by cutting the lip seal from a thickened wall portion or by indenting the wall of the tubular at the seal location, for example by rolling.

Expansion of the inner tubular may be achieved by any appropriate means, including fixed diameter or compliant cones or mandrels, which are axially translated through the tubing to extend the tubular wall. Preferably, the inner tubular is expanded by rotary expansion, that is by rotating an expansion

device carrying an expansion member in contact with the inner wall of the tubular such that the expansion member induces compressive yield of the tubular, reducing the wall thickness with a corresponding increase in diameter. The expansion may be fluid pressure-assisted.

Preferably, the inner tubular is plastically deformed, such that the increased diameter of the tubular is retained without physical support after the expansion force is removed. The lip seal may also be plastically deformed between the tubulars. Most preferably, the lip seal has a degree of resilience and is at least elastically deformed on expansion of the inner tubular such that, following removal of the expansion force, at least a portion of the lip seal, typically the free end of the seal, is urged into sealing contact with the other tubular. The resilience may be inherent in the material forming the lip seal, or alternatively or in addition the seal may be provided in combination with a resilient element, for example a polymeric or elastomeric member provided between a portion of the lip seal and said one of the tubulars.

In one embodiment of the invention the seal arrangement may be provided in combination with a coupling or connector, and may serve to seal the coupling. The invention has particular utility in combination with threaded connectors, as on expansion conventional threaded connectors tend to lose

torque and sealing capabilities. In a preferred embodiment the seal arrangement is provided in combination with a connector that is adapted to maintain or hold torque post-expansion. In this embodiment a substantially conventional threaded coupling may also be provided to provide an initial torque and pressure-tight seal. The lip seal is preferably provided on the inner tubular. The lip seal may be provided at any appropriate location, but is preferably provided towards a free or leading end of the inner tubular. The diameter of the inner tubular may be reduced at the seal location to protect the seal, provided on an external face of the tubular, when the connector is being made up.

According to a further aspect of the present invention there is provided an expandable tubular coupling comprising a first expandable tubular adapted for coupling to a second expandable tubular, at least one of the tubulars comprising an axially extending lip seal.

According to another aspect of the present invention there is provided a method of coupling expandable tubulars, the method comprising:

- providing an axially extending lip seal on one of the tubulars;
- coupling the tubulars; and
- expanding the tubulars such that the lip seal forms a sealing contact with the other of the tubulars.

The tubulars may feature male and female connector portions. The lip seal may be provided on either a male or female portion, but is preferably provided on a male connector portion. The lip seal may be provided at any appropriate location, but is preferably provided towards a free or leading end of the male connector portion. The diameter of the inner tubular may be reduced at the seal location to protect the seal when the coupling is being made up.

The coupling may be used in connecting a wide range of tubular members, particularly members to be located downhole, including casing and liner. In these cases the lip seal may provide a metal-to-metal seal between the tubulars.

Preferably, the lip seal is integral with one of the tubulars. Thus, the lip seal will typically be formed of the same or similar material as the tubular, typically a metal, although the lip seal may be treated to provide different material properties than other parts of the tubular. Alternatively, the seal may be in the form of a separate member.

Preferably, a plurality of lip seals are provided on said one of the tubulars. The lip seals may extend in a common axial direction, or seals may be provided which extend in opposite axial directions.

Expansion of the coupled tubulars may be achieved by any appropriate means, including fixed diameter or compliant cones

or mandrels, which are axially translated through the tubing to extend the tubular wall. Preferably, the coupled tubulars are expanded by rotary expansion, that is by rotating an expansion device carrying an expansion member in contact with  
5 the inner wall of a tubular such that the expansion member induces compressive yield of the tubular, reducing the wall thickness with a corresponding increase in diameter. The expansion may be fluid pressure-assisted.

Preferably, on expansion of the coupling the lip seal is  
10 plastically deformed between the tubulars. Most preferably, the lip seal has a degree of resilience and is at least elastically deformed on expansion of the coupling such that, following removal of the expansion force, at least a portion of the lip seal, typically the free end of the seal, is biased  
15 into sealing contact with the other tubular. The resilience may be inherent in the material forming the lip seal, or alternatively or in addition the seal may be provided in combination with a resilient element, for example a polymeric or elastomeric member provided between a portion of the lip  
20 seal and said one tubular.

The coupling may include a threaded connector, which may be substantially conventional; the threaded connector may provide an initial torque and pressure-tight seal. In a preferred embodiment the coupling includes a torque-resisting  
25 arrangement adapted to maintain or hold torque post-expansion.

## BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

5        Figures 1, 2 and 3 are schematic illustrations showing formation of a seal between an expandable inner tubular and an outer tubular in accordance with an embodiment of the present invention;

10       Figures 4, 5 and 6 are schematic illustrations showing formation of a seal between an expandable inner tubular and an outer tubular in accordance with another embodiment of the present invention;

15       Figures 7, 8 and 9 are schematic illustrations showing formation of a seal between an expandable inner tubular and an outer tubular in accordance with a further embodiment of the present invention; and

20       Figures 10, 11 and 12 are schematic illustrations showing make-up and expansion of a coupling between expandable tubulars in accordance with an embodiment of a further aspect of the present invention.

## DETAILED DESCRIPTION OF THE DRAWINGS

Reference is first made to Figures 1, 2 and 3 of the drawings, which are schematic illustrations showing formation  
25       of a seal between an expandable inner tubular in the form of a

section of liner 10 and an outer tubular in the form of a section of casing 12, in accordance with an embodiment of the present invention.

The liner 10 includes a circumferential indent or channel 14. Within the channel 14 are five lip seals 16 which extend radially and axially from the floor of the channel 14. In this particular example, the liner 10 has originally been provided with a thickened wall portion which has then been cut to form the channel 14 and the seals 16. It will also be noted that with the liner 10 in the original unexpanded configuration, as illustrated in Figure 1, the free ends of the seals 16 lie within the outer diameter of the adjacent parts of the liner 10. This serves to protect the lip seals 16 from damage when the liner 10 is run into a bore and into the casing 12.

To create the desired seal between the liner 10 and the casing 12, an expansion tool, in this case an expansion mandrel or cone 18, is run through the liner 10 as illustrated in Figure 2. As the cone 18 is translated through the liner 10 the diameter of the liner 10 is increased. Depending upon the particular application, the diameter of the liner 10 may be increased to slightly less than or the same as the inner diameter of the casing 12, or the liner diameter 10 may be increased to an extent that the diameter of the casing 12 is also increased.

The passage of the cone 18 past the seal location causes the floor of the channel 14, and thus the lip seals 16, to be pushed out such that the free ends of the lip seals 16 are brought into contact with the inner wall of the casing 12.

5 The lip seals 16 will be both plastically and elastically deformed and thus the free ends of the seal 16 will be urged into contact with the casing 12.

The presence of the lip seals 16 will likely cause a greater elastic recovery of the liner in the region of the seals 16 after the expansion cone 18 has passed, and this is illustrated in somewhat exaggerated form in Figure 3 of the drawings.

10

Reference is now made to Figures 4, 5 and 6 of the drawings which are schematic illustrations showing formation of a seal between an expandable inner tubular in the form of a liner 30 and an outer tubular in the form of casing 32. The arrangement is substantially the same as that described with respect to Figures 1, 2 and 3 above, however in this embodiment the expansion is achieved by means of a rotary expansion device, a roller 34 of the expansion device being shown in Figure 5.

15

20

Due to the presence of the lip seals 36 it may not be possible to increase the inner diameter of the liner 30 in the region of the seals 36 to the same extent as the adjacent portions of liner 30, and accordingly it may be necessary to

25



carry out the expansion of the liner 30 utilising a compliant expansion device, that is one in which the expansion members may be radially inwardly deflected.

Reference is now made to Figures 7, 8 and 9 of the drawings, which are schematic illustrations showing formation of a seal between liner 50 and surrounding casing 52. In this embodiment the spaces between the lip seals 54 are at least partially filled with a soft metal or a polymer 56, or a mix of both. A soft metal infill will deform and flow on expansion of the liner 50 to assist in the creation of a pressure tight seal, while an elastomeric polymer infill 56 will tend to energise the deformed lip seals 56, urging the seals outwardly into sealing contact with the inner wall of the casing 52.

In the above-described embodiments it will be noted that the lip seals 16, 36, 54 are inclined from right to left as illustrated in the Figures. This seal configuration is particularly useful in resisting a fluid pressure differential between the liner casing which would act from left to right as such a pressure differential will tend to further energise the seals.

Reference is now made to Figures 10, 11 and 12 of the drawings which are schematic illustrations showing the makeup and expansion of a coupling 70 between expandable tubulars 72,

74 in accordance with an embodiment of a further aspect of the present invention.

The coupling 70 comprises conventional male and female threaded portions 76, 78. However, on a leading end of the male threaded portion 76 is a roll reduced portion 80 carrying a number of radially and axially extending lip seals 82. The female coupling portion 78 is provided with a corresponding high finish seal land 84 against which the free ends of the lip seals 82 are positioned when the coupling 70 is made up as illustrated in Figure 11.

For use in coupling downhole tubulars, the coupling 70 will initially be made up on surface and the coupled tubulars then run into an appropriate downhole location.

On expansion of the coupling 70, as illustrated in Figure 12, it is possible that the seal initially provided by the conventional threaded portion of the coupling will be lost. However, the expansion tool 86 will expand the roll reduced end portion 80 carrying the lip seals 82 such that the lip seals 82 are deformed into gas tight sealing engagement with the seal land 84. Thus the seal provided by the lip seals 82 will render the original thread seal redundant.

It will be apparent to those of skill in the art that the above-described embodiments of the various aspects of the present invention provide simple and effective sealing arrangements particularly suited for use with expandable

tubulars. It will further be apparent to those of skill in the art that the above-described embodiments are merely exemplary of the present invention, and that various modifications and improvements may be made thereto without departing from the scope of the present invention.

5

## CLAIMS

1. A seal arrangement comprising:  
5 an expandable inner tubular; and  
an outer tubular,  
at least one of the tubulars comprising an axially  
extending lip seal.
- 10 2. The seal arrangement of claim 1, wherein seal arrangement  
is adapted to be located downhole.
3. The seal arrangement of claim 2, wherein at least one of  
the tubulars is in the form of at least one of casing, liner,  
15 a packer and metal clad.
4. The seal arrangement of any of the preceding claims,  
wherein the lip seal is adapted to form a metal-to-metal seal  
between the tubulars.
- 20 5. The seal arrangement of any of the preceding claims,  
wherein the lip seal is integral with one of the tubulars.
6. The seal arrangement of claim 5, wherein the lip seal is  
25 integral with the inner tubular.

7. The seal arrangement of any of the preceding claims, wherein the lip seal is formed of the same or similar material as said one of the tubulars.

5

8. The seal arrangement of any of the preceding claims wherein the lip seal is of metal.

9. The seal arrangement of any of the preceding claims, wherein a plurality of lip seals are provided.

10

10. The seal arrangement of claim 9, wherein the lip seals extend in a common axial direction.

11. The seal arrangement of claim 9, wherein the lip seals extend in different axial directions.

15

12. The seal arrangement of any of the preceding claims, wherein the inner tubular describes an outer diameter and the lip seal is mounted on the inner tubular and initially describes the same or a smaller diameter.

20

13. The seal arrangement of claim 12, wherein the lip seal is provided in a recess in the inner tubular.

25

14. The seal arrangement of claim 13, wherein the wall thickness of the tubular is substantially maintained at the seal location.

5 15. The seal arrangement of any of the preceding claims, wherein the lip seal is plastically deformable.

16. The seal arrangement of any of the preceding claims, wherein the lip seal is elastically deformable.

10

17. The seal arrangement of any of the preceding claims, further comprising a deformable element between a portion of the lip seal and said one tubular.

15 18. The seal arrangement of any of the preceding claims, further comprising a polymeric element between a portion of the lip seal and said one tubular.

19. The seal arrangement of any of the preceding claims,  
20 further comprising a soft metal element between a portion of the lip seal and said one tubular.

20. The seal arrangement of any of the preceding claims, in combination with an expandable coupling.

25

21. The seal arrangement of any of the preceding claims,  
in combination with a threaded coupling.

22. The seal arrangement of any of the preceding claims, in  
5 combination with an expandable coupling adapted to hold torque  
post-expansion.

23. The seal arrangement of any of the preceding claims,  
wherein the lip seal is provided at or towards a free end of  
10 the inner tubular.

24. A method of forming a seal between an expandable inner  
tubular and an outer tubular, the method comprising:

providing an axially extending lip seal on one of the  
15 tubulars; and

expanding the inner tubular such that the lip seal  
contacts the other of the tubulars.

25. The method of claim 24, wherein expansion of the inner  
20 tubular energises the lip seal.

26. The method of claim 24 or 25, wherein expansion of the  
inner tubular urges at least a free end of the lip seal into  
contact with the other of the tubulars.

27. The method of any of claims 24 to 26, wherein the expansion of the inner tubular takes place downhole.

28. The method of any of claims 24 to 27, wherein the lip  
5 seal provides a metal-to-metal seal between the tubulars.

29. The method of any of claims 24 to 28, comprising forming the lip seal by cutting material from the wall of said one of the tubulars.  
10

30. The method of any of claims 24 to 29, further comprising indenting the wall of said one of the tubulars at the lip seal location.  
15

31. The method of any of claims 24 to 30, further comprising mechanically expanding the inner tubular.

32. The method of claim 31, comprising mechanically expanding  
20 the inner tubular utilising a fixed diameter expansion tool.

33. The method of claim 31, comprising mechanically expanding the inner tubular utilising a compliant expansion tool.



34. The method of any of claims 31 to 33, comprising expanding the inner tubular by passing an expansion mandrel therethrough.

5 35. The method of any of claims 31 to 34, comprising expanding the inner tubular by rotary expansion.

36. The method of any of claims 24 to 35, comprising expanding the inner tubular by application of fluid pressure  
10 thereto.

37. The method of any of claims 24 to 36, wherein the inner tubular is plastically deformed.

15 38. The method of any of claims 24 to 37, wherein the lip seal is plastically deformed.

39. The method of any of claims 24 to 38, wherein the lip seal is elastically deformed.

20

40. An expandable tubular coupling comprising first and second expandable tubulars, the first expandable tubular adapted for coupling to the second expandable tubular, at least one of the tubulars comprising an axially extending lip  
25 seal.

41. The coupling of claim 40, wherein the tubulars comprise male and female connector portions.

5 42. The coupling of claim 41, wherein the lip seal is provided on one of the connector portions.

43. The coupling of claim 42, wherein the lip seal is provided on a male connector portion.

10

44. The coupling of claim 43, wherein the lip seal is provided at a free end of the male connector portion.

15 45. The coupling of claim 43 or 44, wherein the diameter of the inner tubular is reduced at the seal location.

46. The coupling of any of claims 40 to 45, wherein the coupling is adapted for location and expansion downhole.

20 47. The coupling of claim 46, adapted for coupling at least one of casing and liner.

25 48. The coupling of any of claims 40 to 47, wherein the lip seal is adapted to provide a metal-to-metal seal between the tubulars.

49. The coupling of any of claims 40 to 48, wherein the lip seal is integral with one of the tubulars.

5 50. The coupling of claim 49, wherein the lip seal is formed of the same material as said one of the tubulars.

51. The coupling of any of claims 40 to 50, wherein the lip seal is of metal.

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52. The coupling of any of claims 40 to 51, wherein a plurality of lip seals are provided.

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53. The coupling of claim 52, wherein the lip seals extend in a common axial direction.

54. The coupling of claim 53, wherein the lip seals extend in opposite axial directions.

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55. The coupling of any of claims 40 to 54, wherein the lip seal is adapted to be plastically deformed.

56. The coupling of any of claims 40 to 55, wherein the lip seal is adapted to be elastically deformed.

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57. The coupling of any of claims 40 to 56, further comprising a deformable element provided in combination with the lip seal.

5 58. The coupling of claim 57, comprising a resilient element provided between a portion of the lip seal and said one tubular.

59. The coupling of claim 57 or 58, comprising a relatively  
10 soft metal element provided between a portion of the lip seal and said one tubular.

60. The coupling of any of claims 40 to 59, wherein the coupling includes a threaded connector.

15 61. The coupling of any of claims 40 to 60, wherein the coupling includes a torque-resisting arrangement adapted to hold torque post-expansion.

20 62. A method of coupling expandable tubulars, the method comprising:

providing an axially extending lip seal on one of the tubulars;

coupling the tubulars; and

expanding the tubulars such that the lip seal forms a  
sealing contact with the other of the tubulars.

63. The method of claim 62, comprising expanding the tubulars  
5 downhole.

64. The method of claim 62 or 63, comprising mechanically  
expanding the tubulars.

10 65. The method of claim 62, 63 or 64, comprising expanding  
the tubulars using a compliant expansion device.

66. The method of any of claims 62 to 65, comprising  
expanding the tubulars using a fixed diameter expansion  
15 device.

67. The method of any of claims 62 to 66, comprising  
expanding the tubulars utilising an expansion cone.

20 68. The method of any of claims 62 to 67, comprising  
expanding the tubulars utilising a rotary expander device.

69. The method of any of claims 62 to 68, comprising  
utilising fluid pressure to expand the tubulars.

70. The method of any of claims 62 to 69, comprising  
plastically deforming the lip seal.

71. The method of any of claims 62 to 70, comprising  
5 elastically deforming the lip seal.

72. The method of any of claims 62 to 71, comprising  
resiliently urging at least an end portion of the lip seal  
radially outwards.

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73. The method of any of claims 62 to 72, wherein the  
tubulars are at least initially connected by a threaded  
connection.

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Application No: GB0417031.2

25

Examiner: Alan Jones

Claims searched: 1-73

Date of search: 26 August 2004

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 24, 40, 62 at least	WO2003/016669 A2 (EVENTURE GLOBAL TECH.) See e.g. fig 2, tubulars 115, 175, lip seals 170a, b & page 4 line 5-6.
X	1, 24, 40, 62 at least	US6431282 A (BOSMA ET AL) See e.g. axial extending lip seal 5, and col. 9 lines 57-63
A	-	WO1998/59151 A1 (CORRE) See e.g. axial extending lips 3
A	-	US3746092 A (LAND) See e.g. seal 105, 205

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>W</sup>:

E1F

Worldwide search of patent documents classified in the following areas of the IPC<sup>07</sup>

E21B

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPODOC, PAJ